Space Weather Technical Forecast

Issued on Wednesday, 29 November 2023 at 01:32 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: M-flares likely (R1-R2 Blackouts). G1/Minor G2/Moderate Storms likely days 2-3 (30 Nov-01 Dec) due to CME arrivals. Chance of S1 Radiation storming day 1 (29 Nov).

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Moderate recently, with a M9.9 flare at 28/1950 UTC, from AR3500. This is the most notable and largest of the thirteen visible sunspot regions and is comprised of a compact cluster of dark umbra, most with penumbra. It retains a complex magnetic structure. All other regions on the disc remain smaller and simpler, and either stable or showing signs of decay.

There are also a number of filaments on the Earth-facing disc. Two of these erupted to produce CMEs, the first alongside the C6.7 at 27/1852 UTC, and the second with a C5.6 flare peaking at 27/2340 UTC. The first produced a weak and slow, but partial halo CME, while the second produced a faster CME that was more off the Earth-Sun line. However both of these have been assessed as having potential Earth-directed components arriving on day 3 and 4 (30 Nov and 01 Dec). The M9.8 flare observed earlier has also given a halo CME, which is very likely to be Earth directed, this has been included in the accompanying forecast but further analysis of imagery is needed to add further detail.

Solar Wind / Geomagnetic Activity: Solar wind speeds have been at slightly elevated winds speeds, around 430-480 km/s. Density has been around average. Interplanetary Magnetic Field (IMF), Bt, was weak varying between 3-5nT, with the north-south component, Bz also varying weakly. Phi angle was mainly positive (away from the Sun). Geomagnetic activity was Quiet.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux remained at background. GOES16 high energy (greater than 2MeV) electron flux has been at Background. The associated 24-hour fluence has remained below the Active threshold (1e8 integrated pfu). The observation at 29/0000 UTC was 3.7e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Low to Moderate with isolated M-flares (R1-R2 Blackout) considered likely, and a slight chance of an isolated X-class flare (R3 Blackout). The plausible source region being AR3500.

Solar Wind / Geomagnetic Activity: Four earth directed CMEs feature in the forecast. Three of which are most likely to arrive day 2 (30 Nov), with the fourth arriving day 3 (01 Dec). These CMEs may interact with one another due to their varying velocities, the later faster CME's may enhance those which left the sun earlier in the period. Aside from the CMEs, the current slightly elevated solar wind from ongoing influence of CH75, is expected to soon ease to background through day 1 or early day 2 (29-30 Nov).

Geomagnetic activity is initially expected to be Quiet with a chance of isolated Unsettled spells. Multiple fast CME arrivals are likely to bring G1/Minor or G2/Moderate geomagnetic storms on day 2 or 3 (30 Nov or 01 Dec) with a slight chance of G3/Strong storms. Geomagnetic activity is the expected to wane into day 4 (02 Dec) with Quiet to Active intervals and a slight chance of a

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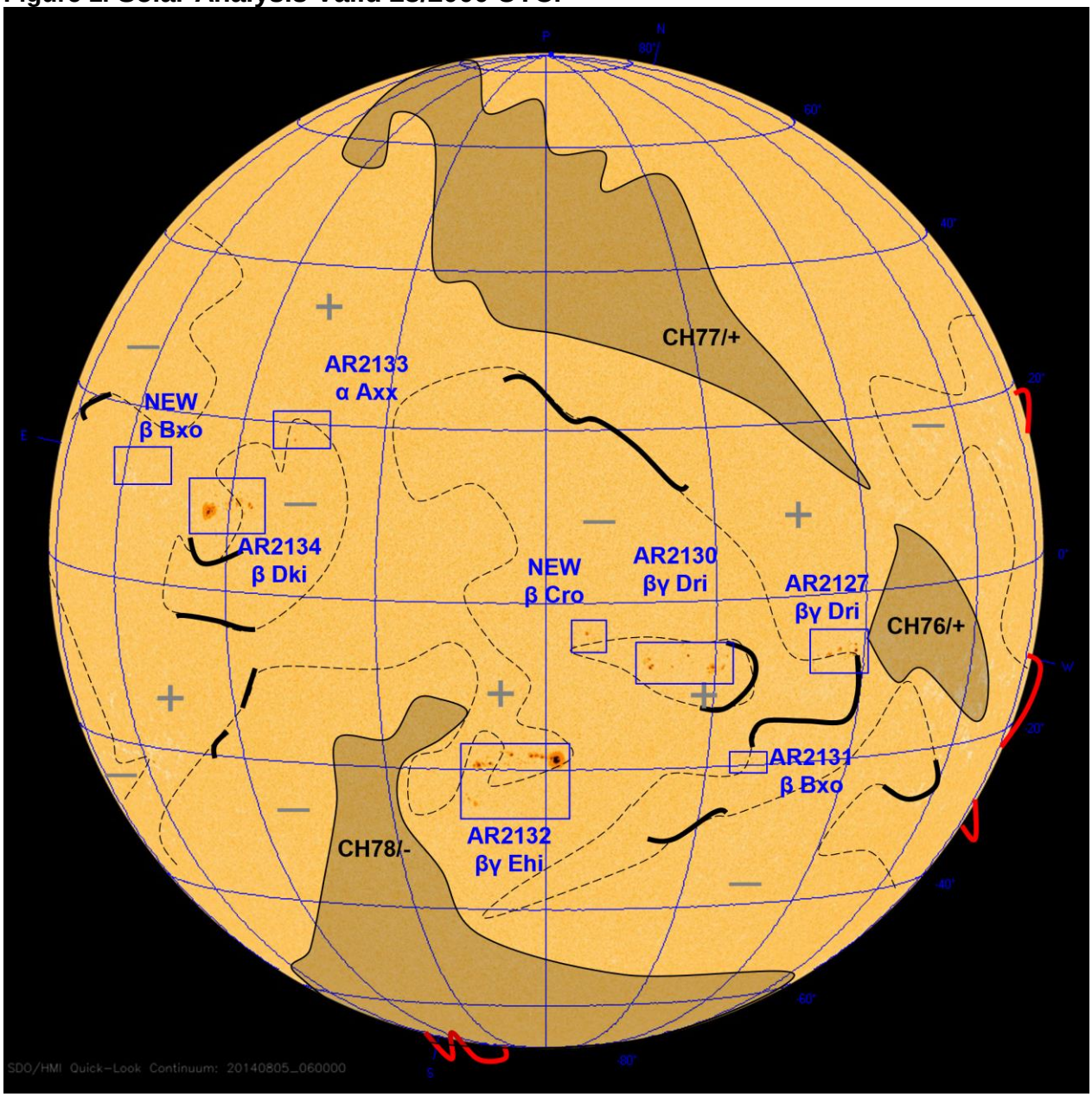
G1/Minor storm.

Energetic Particles / Solar Radiation: GOES16 high energy proton flux is expected to remain at background levels. There is a chance of flux levels approaching or perhaps exceeding the S1 level early day 1 (29 Nov) due to the M9.8 flare from AR3500 on 29 Nov, otherwise the risk reducing to a slight chance should any further significant flares or filament eruptions occur. Electron flux is currently at background, but perhaps trending towards moderate or high on diurnal peaks through day 1 (29 Nov). Any increase is likely to be suppressed again by the possible CME arrivals. The associated fluence may increase in response, but expected to stay below the Active (1e8 integrated pfu) threshold.

Figure 1. Solar Analysis Valid 28/2000 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

There are up to four Earth-directed CMEs.

Two glancing impacts are possible on 30 Nov. The first was due to a filament eruption from the southwest disc around 27/0535 UTC off the southwest disc. This has been reanalysed and is forecast to give a glancing impact on day 2 at 30/0700 UTC, with the bulk of the material passing south of earth. The second is due to a large filament eruption off the northeast disc 27/2340 UTC. This is a faster CME, that is expected to largely miss behind and north of Earth, however there is a potential for a glancing impact either later on day 2 (30 Nov), perhaps combining to enhance the first arrival.

The third is due to a filament eruption from the northeast disc around 27/1840 UTC, coincident with a C6.7 flare from AR3500 in the southeast. A subsequent faint partial halo CME was observed heading southeast. This is more likely to impact Earth than the above eruptions, however this is a slower CME, and not expected to arrive until day 3, around 01/1800 UTC.

The fourth CME was a large halo CME signature from the M9.8 flare at 28/1950 UTC. The imagery for this CME is still being processed and as of yet has not been inputted into ENLIL. This CME is very likely to be Earth directed and estimations for the speed rages from 800-1100 km/s currently. This could give an arrival time sometime between 0900-2400 on 30 December. The risks of geomagnetic storms on days 1 and 2 have therefore been preliminarily increased, though are likely to be adjusted further with future analysis and clarity.

Aside from the CMEs solar winds are expected to ease to background through day 1 or early day 2 (29-30 Nov) as the influence of coronal hole 75 recedes. No further coronal hole source enhancements are expected.

Geomagnetic activity is initially expected to be Quiet with a chance of isolated Unsettled spells. Multiple fast CME arrivals are likely to bring G1/Minor or G2/Moderate geomagnetic storms on day 2 or 3 (30 Nov or 01 Dec) with a slight chance of G3/Strong storms. Geomagnetic activity is the expected to wane into day 4 (02 Dec) with Quiet to Active intervals and a slight chance of a G1/Minor storm.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	10	70	60	20
Strong	G3	No	1	20	10	1
Severe	G4	No	1	5	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

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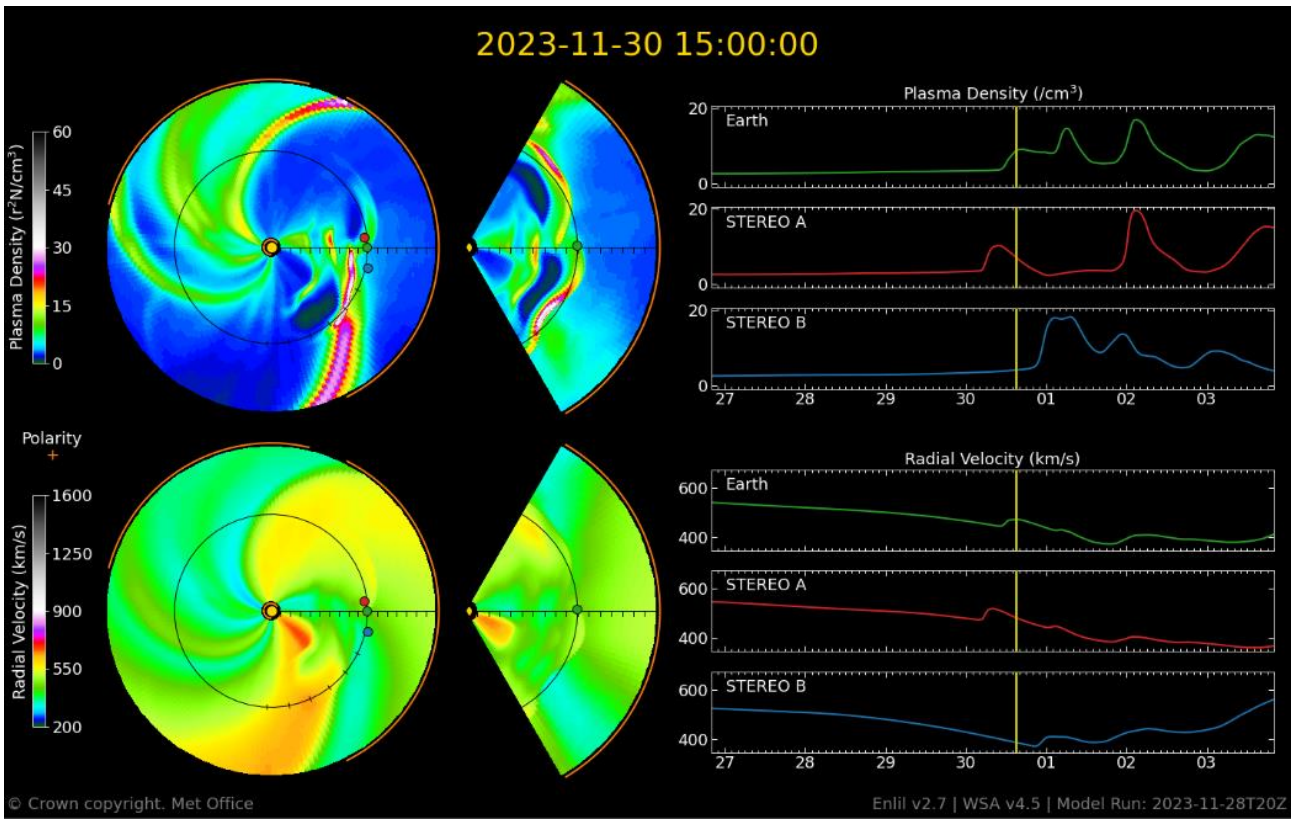
Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
27/1235	Nil	Filament	SW	575 km/s	Early 30 Nov	Glancing impact
28/0302	Partial	Filament	NE	1040 km/s	Late 30 Nov	Glancing impact. Low confidence.
28/0800	Partial	Filament and C6.7 AR3500	NE/SE	380 km/s	Late 01 Dec	Minimal impact expected
28/2330	Full	M9.9 3500	S	800-1100 km/s	30th Nov or early 01 Dec	Likely G1/G2 but further assessment necessary.

Figure 2: MOSWOC ENLIL (please note this does not include the final large and fast halo CME)



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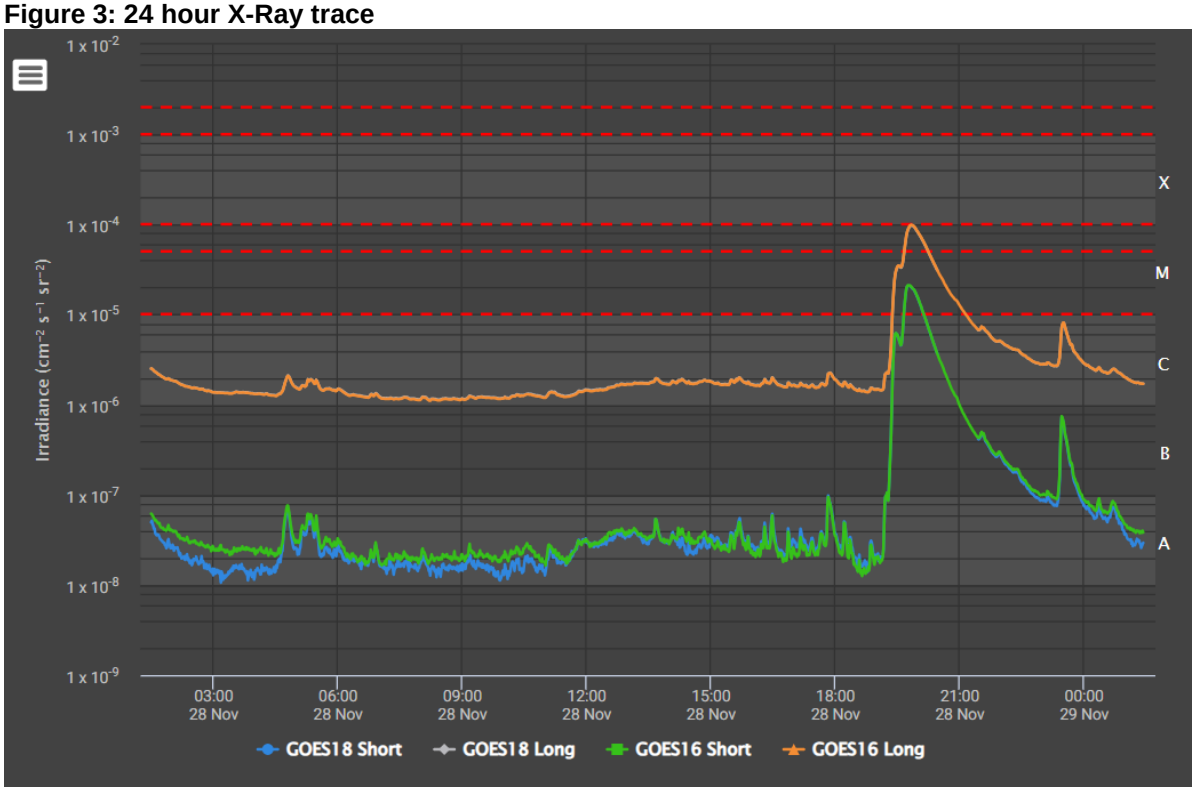
Radio Blackouts - X-Ray Flares:

Low to Moderate activity is forecast, with a likelihood of isolated M-flares.

There are thirteen sunspots on the disc. AR3500 remains the main region of interest, comprised of a number of compact umbra with surrounding penumbra. However, the previous separation of the positive and negative polarity regions remains, losing its delta configuration but retaining some complexity as a beta-gamma. The other regions remain smaller and simpler. Four unnumbered spots are present on the disk, two having emerged around the eastern limb during 28 Nov, all seemingly stable at present. Low to Moderate activity is forecast with M-class flares considered likely, and a slight chance of an isolated X-class flare. Should these occur, the most likely source region remains AR3500.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	No	60	60	60	60
Very Active	R3 to R5 X Class	No	20	20	20	10

Figure 3: 24 hour X-Ray trace



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Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 is currently at background. There are number of moderately sized sunspot regions on the disc, however the majority of these are magnetically simple mature spots with no significant activity. The main region of note is currently AR3500 in the southeast. This spot gave an M9.8 flare at 28/1950 UTC and although there is yet to be a proton response from this, the risk of S1 has increased for day 1 given this activity. There are also a number of filaments on the Earth-facing disc, and large eruptions, especially off the west disc, can result in proton flux increasing at Earth, albeit likely staying below the S1 Minor Radiation Storm level.

Overall this gives a chance of elevated protons on day 1 (28 Nov), reducing to a slight chance thereafter.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	30	10	10	10
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) as observed by GOES-16 is currently at background in the presence of a slightly elevated solar wind. As the solar wind speed eases through day 1 (29 Nov) a slight increase in electron flux values is possible, likely rising to moderate levels and potentially to high levels on diurnal peaks. However any increases are subject to the possible CME arrivals from day 2 onward (30 Nov-02 Dec), which are likely to further suppress values.

Overall electron fluence is expected to remain below the Active threshold (1e8 integrated pfu). This is supported by REFM.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	1	1	1
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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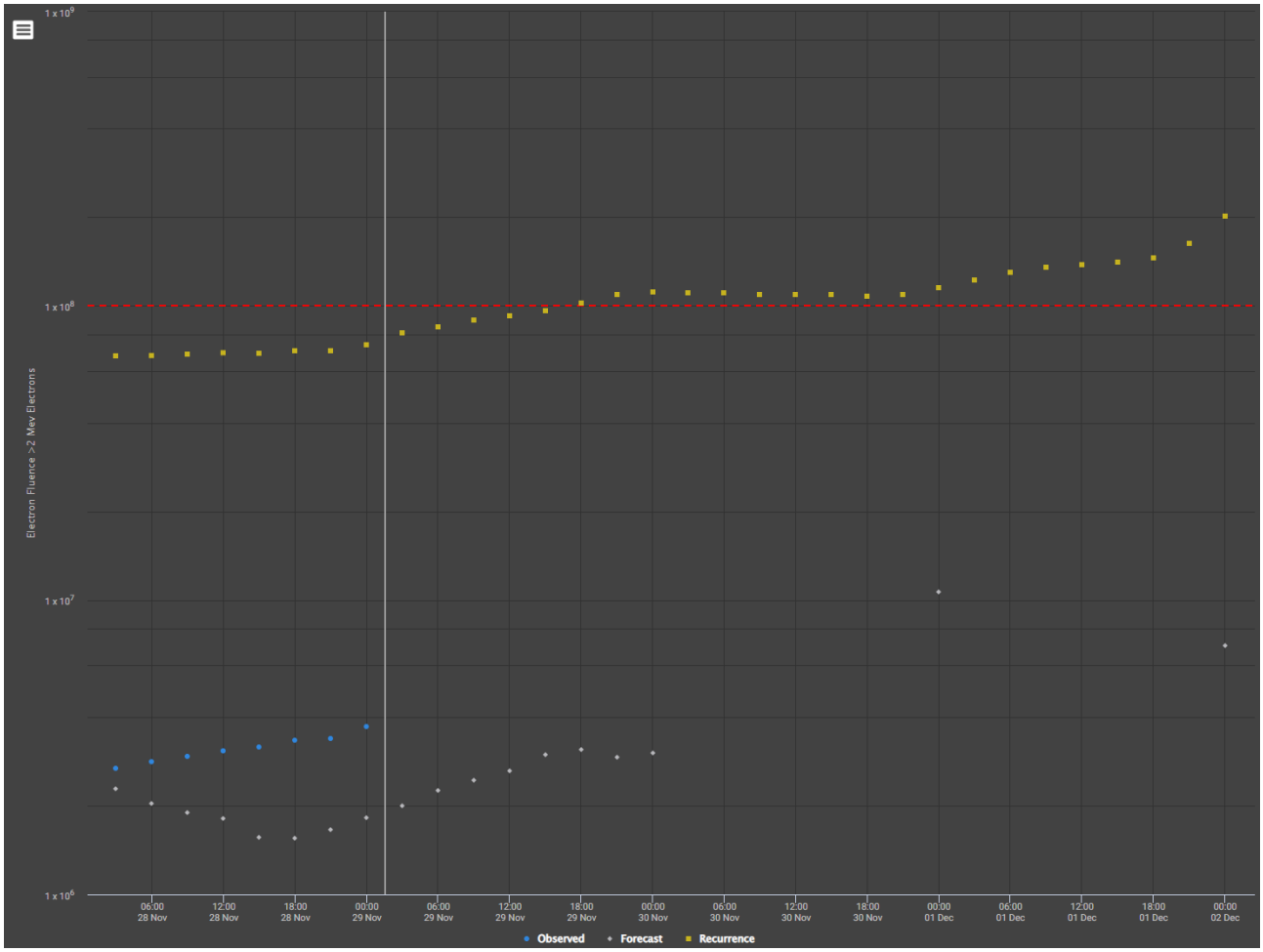
Figure 4: REFM integrated flux and fluence.



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